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50. Internationales Wissenschaftliches Kolloquium
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D. Băcescu / H. Panaitopol / M. D. Băcescu / L. Bogatu

Complex Equipment for Adaptive Control of a Robot

ABSTRACT

The paper presents the authors preoccupation regarding the design and the build of sensors used to adaptive control of mobile minirobots, but which are not part of robot structure. Is reviewed the historical evolution of some optoelectronical sensors, which is grouping into a family, and in the end of papers is present an equipment which can use simultaneous transducers that functioned with lighting, radio and ultrasound waves. In this way, if in a workspace appear obstacles which interrupt the light radiation, the control of minirobot is taken by the other transducers.

INTRODUCTION

Within the department of precision mechanics and Mechatronics, from Politehnica University of Bucharest, in the last time, was developed some optoelectronic sensors able to determine the distance to a light source or normal direction of a plane determined by the three light sources. These researches were made for mechatronics applications bind of minirobots control.

In many cases, the sensorial equipment of minirobots is too large and heavy to be carried by them. A reliable solution in order to simplify the construction of a minirobots and its maneuverability is to transfer the sensorial equipment to a tracking and control installation.

For tracking and adaptive control of a minirobot with one of the optoelectronic sensors, presented in this paper, is used the triangulation principle and the comparison between position of a minirobot into real workspace and the equivalent position of a virtual minirobot into virtual workspace.

In this case, the real workspace has to be known a priori, with all the forms and dimensions of the obstacles. The optoelectronic equipment for tracking and adaptive control determines, in real-time, the minirobot position into the real workspace. Any command given to the minirobot at certain moment of time is previously checked into virtual workspace.

Further is presented four type of optoelectronic sensors designed and build of the authors of the paper with the purpose of development of adaptive control and virtual sensors concepts.

FAMILY OF OPTOELECTRONIC SENSORS

The schematic of the first optoelectronic sensor of family is shown in fig. 1. The plane whose normal direction must be determine by means of optoelectronic sensors is defined by the three light sources (laser diode) placed on a sphere with the center O_1 and radius R. The imagines of these light sources are formatted by some objectives whose center are on the circle with r radius and placed on rotating plane PR, which contain a straight photosensitive sensor LF.

Imagine of one light source is formatted by the objective Ob_a on the rotating plane PR that has angular velocity w. At a moment, straight photosensitive sensor LF meet the imagine C_i at the time t_{ij}; i = 1...3 is the number of light sources and j = 1...2 is the number of objectives.

The schematic of the second optoelectronic sensor of family is shown in fig. 2. This sensor is based on the stereoscopic correspondence of images of an object build by nonlinear three light sources.

The imagines of these, which are in stereoscopic correspondence, are modulate with an opto-mechanical system and transformed into *phase coordinate* of electrical signal. The processing of these signals leads to calculate the directory cosine of normal direction of a plane defined by the three light sources.

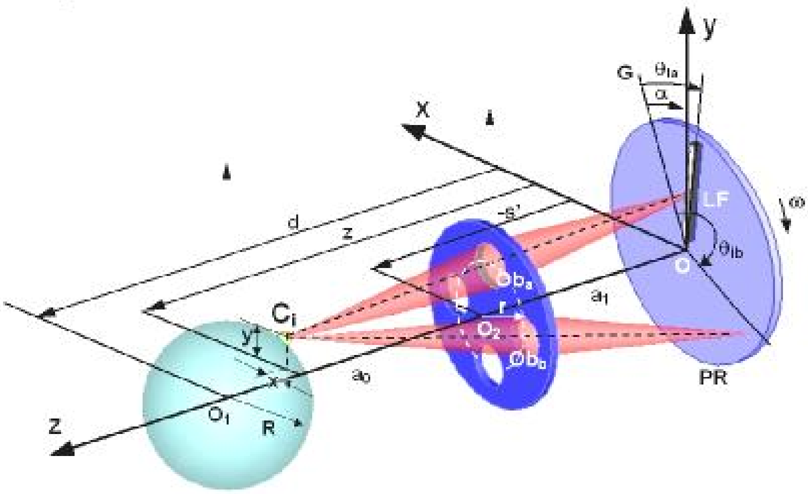

Fig. 1. The schematic of the first optoelectronic sensor of the family used for determine of direction [2]

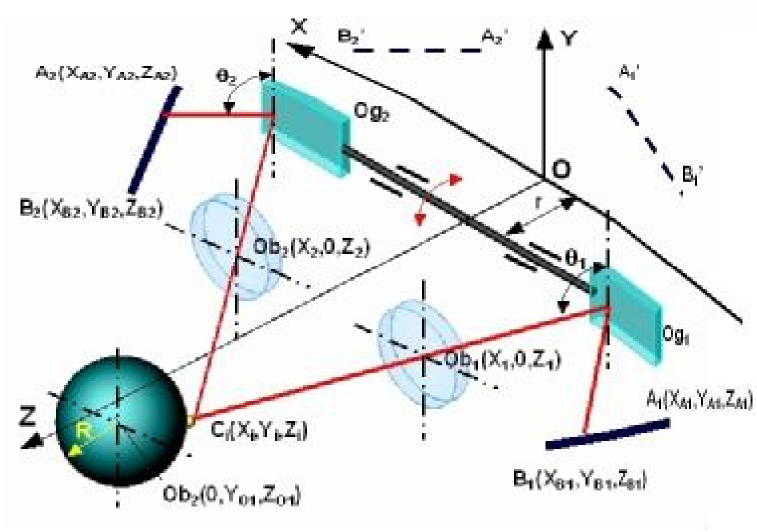

Fig. 2. The schematic of the second optoelectronic sensor of the family used for determine of direction [2]

In [3], [4] is shown that the normal direction of a plane determined by the three light sources depend on the time t_{ij}. This type of sensor has two disadvantages. First of all is a bad accuracy because the stereoscopic base is small. A second disadvantages is that it must maintain a constant distance between sensor and the sphere.

Imagine of one light source C_i placed on a sphere with the center O_1 and radius R, formatted by the objective Ob_1, is put into coincidence with straight photosensitive sensor A_1B_1, after reflection on rotating mirror Og_1, at time t_1 when mirror rotation angle is q_1. The light radiation that start from the light source C_i reaches, due to objective Ob_2 and the mirror Og_2, in coincidence with a straight photosensitive sensor A_2B_2 at the time t_2, when mirror rotation angle is q_2.

The same thing is happened for each light source and finally is obtained two signals with specific phase offset in terms of relative position of the sphere. These signals are picked and processing by means of a data acquisition system in order to determine the normal direction of the plane determined by the three light sources.

This optoelectronic sensor has a better accuracy because the stereoscopic base is bigger that the first optoelectronic sensor, but it must maintain a constant distance between sensor and the sphere.

The schematic of the third optoelectronic sensor of family is shown in fig. 3.

The sensor has an objective *Ob* and a quadratic photosensitive sensor *FE* with four identically photoconductive zones. When the optical axis is on the direction of light source *S*, the signals from the four photoconductive zones are equal and if it is known the position of the axis is known the direction *ObS*.

The tracking movement of light source *S* is produced by the stepping motors M_1 şi M_2 by means of two warm-gear reducers, m_1-rm_1 and m_2-rm_2. Encoder TIRO1 achieves measurement of the rotational angle α, and encoder TIRO2 achieves measurement of rotational angle β.

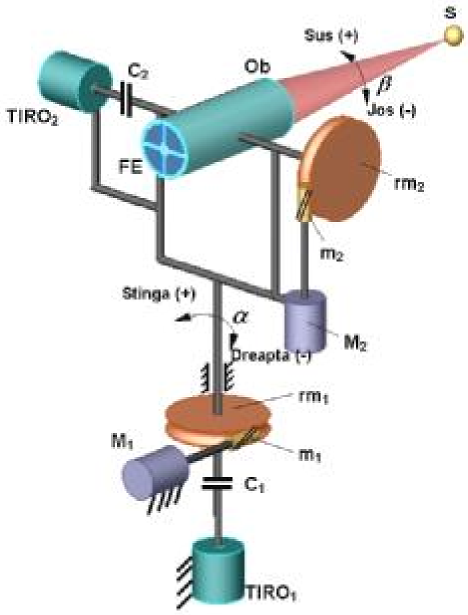

Fig. 3. The schematic of the third optoelectronic sensor of the family used for determine of direction to a light source [2]

The control of the sensor is achieved by the personal computer by means of data acquisition board. The signals from the photoconductive zones give information about the orientation of deviation from direction of light source *S* and the motors are maneuvered so that to minimize this deviation. In the moment in which all the signals are equal, the axis of the sensor is on light source direction *S,* it is transferred in the memory of personal computer the content of the incremental counters of electronically module and is compute the angles α and β.

This optoelectronical sensor is able to tracking and determines, permanently the direction to a light source, without to determine the distance between sensor and the light source. To determine the distance to the light source needs two identical sensors mounted so that the triangulation principle to be applied.

In this case the system enable to determine accurately two coordinates of the light source irrespective of its position. This system has two disadvantages. One of them is that the system cannot simultaneous tracking three light sources which to determine a plane. The second disadvantage is that the system has a large price.

The fourth type of optoelectronic sensor is shown in fig. 4. The optoelectronic sensor determines the spatial position of a number of light sources P_j, placed on a movement object (e.g. on a minirobot that must be controlled). The optoelectronic sensor is in fact an installation made by three identically modules, namely M_1, M_2 and M_3, which materialized a three-dimensional co-ordinate system thereupon is refereed the controlled displacement of a movement object (robot).

The characteristic element of each module is a rotating mirror. By means of an objective, the mirror places the light source image on a straight photosensitive sensor, whose axis is parallel with mirror axis. Also, each module has three coplanar photo-collimators placed perpendicularly on mirror axis. The angles between the photo-collimators are known. The first photo-collimator has an IR LED and the others a receiver IR sensor each. When the perpendicular of rotating mirror coincides with the bisector of angle between first and second photo-collimator than three counters start. The first counter stops when the mirror perpendicular coincides with second receiver collimator axis. The next two counters stop when the images of the other two light sources “touch” the straight photosensitive sensor. The numbers latched into the counters allow computing the rotating mirror angular velocity and the angle between the plane defined by mirror axis and light source P_1 and the plane xOy of the spatial orthogonal reference system.

For three nonlinear light sources attached to the movement object it is possible to calculate the spatial position of them and therefore the normal direction of a plane determined by the three light sources.

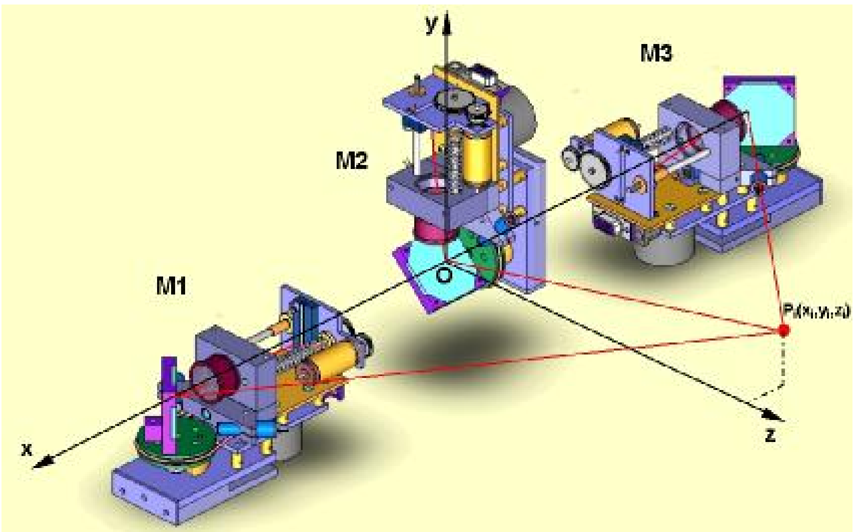

Fig. 4. The Optoelectronic sensor, which materialized a three-dimensional co-ordinate system [1]

This capability can be used to create an adaptive control for a minirobot and to endow with virtual proximity, direction and angular sensors.

The last optoelectronic installation has worked very well being tested for control of a walking minirobot with pneumatic actuators, into a circular workspace with a 3 m radius.

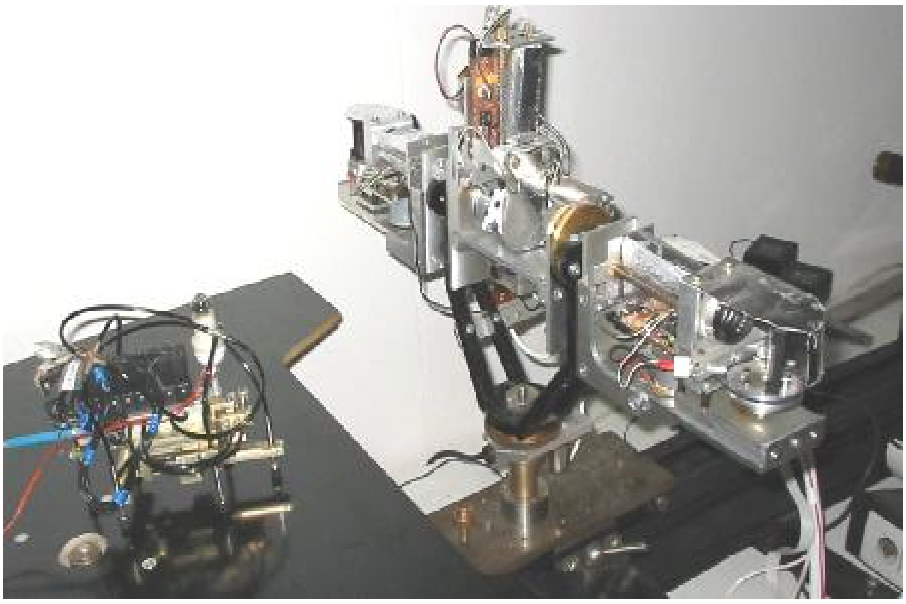

Fig. 5. The image of the optoelectronic equipment and the minirobot [4]

The image of the optoelectronic equipment that was made experimentally is shown in fig. 5.

The control of minirobot was made by adaptive control strategy as shown in papers [1] and [3], where was introduced the virtual sensor concept. This concept completes the possibilities of minirobot control into a complex workspace. However the function of the installation in a complex workspace rely on a restrictive assumption: between the optoelectronic equipment and the light source of minirobot never must be an opaque obstacle that to interrupt the light radiation. The experiments in this restrictive assumption were made into a plane workspace, which was drowning different obstacles.

THE DEVELOPMENT OF A NEW EQUIPMENT

After the studies and researches performed in the last time in this field, the authors suggest the development of new equipment functioning on the same principles, but with higher precision and using signals that can eschew or penetrate the obstacles.

The increasing of the equipment precision is bind of increasing the stereoscopic base [1].

If the stereoscopic base is increased to dozens of meters, then it is difficult to make a common frame for the elements of the equipment. In this case, a construction made by two or three identical modules, optical aligned on common axis, represents a new approach for complete the sensorial equipments family.

With the purpose of assurance the work of the equipment in complex situations like eschew or penetrate the obstacles by used signals, it is proposing that each module to have the possibility of simultaneous utilization with an optical transducer, with an ultrasound transducer and with a radio wave transducer. In this way, when a situation appears - in witch one or couples of transducers are incapable to received signals - the remains ones assure the functionality of the equipment. Also, another important aspect of simultaneous functionality of the three transducers types is the advantage of mutual completion of its performances.

The optoelectronic transducer of the new equipment will utilize optoelectronic devices for transforming geometric angles in processing time units, as in already studied solution [2], and the others types of transducers will utilize to indicate the aim direction, an incremental rotation transducer, attached to the platform on witch they are placed.

Each component module of the new equipment will be made like a research platform witch must have the following possibilities:

- Must have a rotary table 1 on witch it can assemble an optoelectronic transducer, an ultrasound transducer, a radio wave transducer, an observation unit or all in the same time by the aide of a special socket 6;
- The rotary table must be electric controlled (2) in a following movement of the direction from where the signal (that will be received) is emitted;
- The table, in its movement, must be in connection with an encoder 5;
- The body on witch is assembled the rotary table must have the possibility to be adjusted with specials screws 3, so that the table is placed in horizontal plan at a well-specified cote.
- The body must have fine and large adjustments 4 for placing the incremental transducer on null position, at the same time with placing the aim transducer on its initial position of the emission source of the processing signals.
- Each module must have an independent compute unit that must send the initial processing data at a unit that will interpret this data and process them till final level.

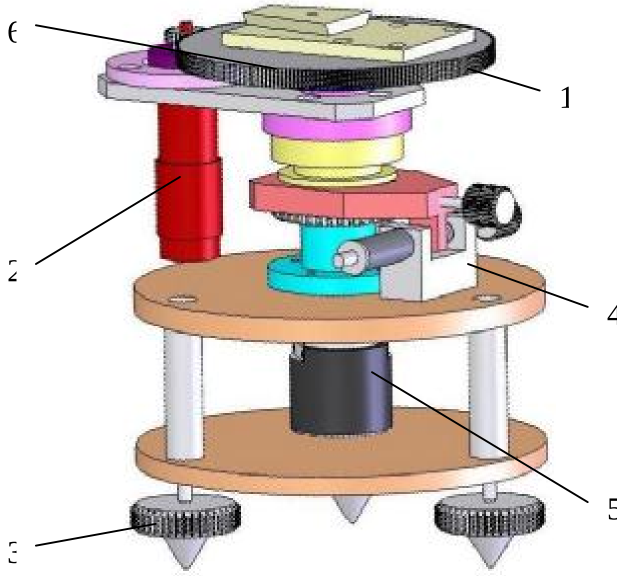

Fig. 6. The research platform for transducers that functioned with lighting, radio and ultrasound waves [4]

CONCLUSIONS

Making a modular construction for the platform at research level allows that the models realized afterwards be easy integrated in real applications. Simultaneous use in platform component of transducers that functioned with lighting, radio and ultrasound waves, with favors consequences regarding mutual completion of proper capacities, allow the development of concepts of virtual robot, virtual space, virtual sensor and adaptive command. This tackle opens the possibility of initiation of new researches in the field of control of autonomous mobiles robots and in other fields as well.

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